US LHC Accelerator Project
Progress Report, 4th Quarter FY 1998
20 November 1998
J. Strait, Project Manager

I. Summary

The Implementing Arrangement was signed in July, and the Project Management Plan is ready for signatures. Re-optimization of the program plan, principally by accelerating the schedule for most of the work, is nearing completion. The cost performance reporting system is not quite operational yet, and a CPR for this quarter will be submitted later. Further progress has been made on the development of an MOU with CERN concerning the safety of mechanical equipment provided by the US laboratories for LHC. The project remains on schedule and overall expenditure are close to the cost estimate.

A third model interaction region quadrupole has been tested with no improvement in quench performance over the previous two models. Following a review in July the R&D program was modified and expanded to focus on the areas in which the excessive quenching occurs. Good progress is being made on all other aspects of the quadrupole design. A conceptual design review for all of the beam separation dipoles was conducted in July and the presented designs were endorsed. Detailed design for two prototypes is underway, and there has been good progress in understanding the interfaces of these magnets with the rest of the LHC. The conceptual designs of the IR feedboxes and absorbers continue to be refined, leading towards conceptual design reviews to be conducting in the next few months. Upgrades to the superconductor test facility continue as planned, and the modest backlog of 4.2 K tests has been cleared out. Evaluation of the prototype eddy current flaw detector indicate that additional measuring heads must be added to allow cold welds to be detected across the full width of the cable. Cabling tests are being performed to support the manufacturing of cable for the main LHC magnets. Good progress continues to be made towards understanding the field quality and correction requirements for the US-provided magnets, electron cloud effects and instrumentation of the IR absorbers. The quality of collaboration between US and CERN accelerator physics continues to grow.

II. Program Planning

The Implementing Arrangement was signed by the LHC Project Leader, L. Evans, the three US laboratory directors, J. Peoples, J. Marburger, and C. Shank, and the US LHC Accelerator Project Manager J. Strait in July. Following considerable discussion with DOE personnel the Project Management Plan has been finalized and will be submitted to DOE for approval in October. Significant changes were made to define more tightly the change control thresholds, and additional level 2 milestones were defined. Figures defining the management structure and project baseline data, including milestones to level 3, the cost estimate to WBS level 3, the obligation profile plan, and the escalation rate table have been moved to appendices to facilitate their maintenance through the change control process.

Re-optimization of the program plan, principally by accelerating the schedule for most of the work, is nearing completion. Accelerated schedules have been prepared for all three of the laboratories' programs and are being reviewed. We hope to make these the new baseline schedules during the coming quarter.

The cost performance reporting (CPR) system is partially operational. Although the accelerated schedules are not yet the official baseline, we are measuring the project progress with respect to them rather than the older schedules. Bugs are being worked out of the cost performance reporting software system together with the reviews and optimization of the new schedules. We are not able at this time to include a CPR with this report which is sufficiently reliable in all its entries to be useful. We will be able to produce accurate monthly CPRs corresponding to the 4th quarter within the next few weeks, which we will forward as an addendum to this report when they are ready.

Further progress has been made on the development of an MOU with CERN concerning the safety of mechanical equipment provided by the US laboratories for LHC. It has evolved from a document concerned only with pressure vessels to one which defines the procedures for reviewing US-provided equipment with respect to mechanical safety and certifying them for use in LHC. Its most important features are that it permits the use of the ASME code and allows most of the safety reviews of each device or system to be done by the US laboratory responsible for the item following its own standard procedures. M. Bona, head of the Technical Services and Environment group of the CERN Technical Inspection and Safety Commission (TIS) visited Fermilab in August to review its safety review procedures, and will conduct similar reviews at BNL and LBNL in November. We still hope to finalize this MOU by the end of the year.

Discussions with Paul Faugeras, head of project planning for LHC at CERN, have lead to improved understanding of how our work will fit in with the CERN configuration control system. We have also gained a clearer understanding of the requirements for writing Functional and Interface Specifications, and have begun to prepare these for several of the US-provided devices.

The Interlab Steering Committee met on 25 September. Topics of discussion included the status and content of the Project Management Plan, the status of cost performance reporting and the equipment safety MOU, a preview of expected upcoming items requiring Change Control Board action, and strategies for the IR quadrupole R&D program. A meeting of the Project Advisory Group is scheduled for early October.

III. Technical Progress

WBS 1.1.1 Inner Triplet Quadrupoles A review of the model magnet program was conducted in July. This followed the tests of the first two model quadrupoles, and was before the assembly of the third was complete. The review committee included three people from outside Fermilab who are not involved in the quadrupole program, two from BNL and one from CERN. Following the review, and based on the observations and recommendations of the reviewers, the quadrupole R&D program was modified. The focus is on improving the support of the coil ends and on containment of the axial component of the Lorenz force. An additional model magnet was added to the plan, as well as a partial re-build of the third model. A new design for the coil ends was initiated, and a number of bench tests to characterize the mechanics of the magnet ends are being performed.

The second model, which was tested during the third quarter, was disassembled and carefully examined for construction flaws in the regions where many of the training quenches occurred. No obvious cause of the quenches could be identified.

Assembly of the third 2 m model quadrupole was completed and it was tested during the third quarter. This model incorporated a number of improvements in the coil fabrication and support of the coil ends. It also includes a new design internal splice between the inner and outer layers, and it was constructed with no longitudinal coil restraint. Its quench training was no better than the first two models, although the quench locations are different in all three models. It is planned to disassemble the magnet partially and reassemble it with an interference fit between the yoke and collars and with modest axial preload to the coil ends.

Coils for the fourth model magnet have been wound and are ready to be assembled. This magnet will use collets to clamp both coil ends and will use an alternate method of restraining the ends in the axial direction. The new 5th model will be built using G10 coil end parts. Winding of these coils has begun. Its mechanical structure will be chosen based on the experience with the rebuilt model 3 and with model 4.

Design work on the cryostat continues. Bids have been received for the construction of the full-scale heat exchanger test cell. It appears that this test will cost considerably more than estimated, and we are currently evaluating several options as to how to proceed. A Conceptual Design Review for the cryostat has been scheduled for December 3.

Design and fabrication of tooling required for the full-length magnets has begun, limited for the moment to those components whose design will not be affected by the on-going R&D program. Design work continues on the feed can and other measurement equipment for the tests of complete magnets. Discussions have begun with a vendor for possible commercial manufacture of the cable for the prototype and production magnets.

Draft interface definition information has been sent to KEK for their comments.

WBS 1.1.2 Interaction Region Dipoles / 1.2.1 RF Region Dipoles A Conceptual Design Review covering all the different variants of these dipoles was held in July. The review committee recognized that the designs presented were very good, and recommended that BNL be given the go-ahead for detailed designs to be developed for model magnets and continued engineering design required for the production magnets. Lists of action items related to the model magnets and to the production design were developed, and BNL is making good progress in addressing these. The concerns raised were mainly related to the cooling scheme, the high current buses for the main LHC magnets that pass through the D4s, and the interfaces to the other LHC equipment. Work is currently concentrating on the design of the 2-in-1 model magnets of the D4A type and of the tooling needed to build them, on understanding all of the interfaces, and on the development of flow schematics related to all of the US-provided dipoles. Three people from BNL visited CERN during the first week of September. Much valuable information was collected about interfaces, electrical buses, the cooling requirements and other boundary conditions. That D4A is now cooled at 1.9K while D2 is cooled at 4.5K has called into question whether it is practical to have a common spare for both. This will be evaluated in the coming months.

<u>WBS 1.1.3 Interaction Region Feed Boxes</u> The conceptual design has been further refined and somewhat simplified. The design was presented at CERN in September, and the concepts were endorsed. A conceptual design review, which will include several members of the CERN staff on the review committee, is scheduled for December 2. A Functional Specification is being prepared.

<u>WBS 1.1.4 Interaction Region Absorbers</u> Work continues on the conceptual designs of the neutral beam absorber (TAN) and front quadrupole absorber (TAS). The TAN design has been modified to simplify assembly and improve the shielding. Two people from LBNL visited CERN in July to discuss matters related to the TAN and TAS designs, including installation, alignment, tunnel layout, vacuum, radiation deposition and activation, the design of the experimental shielding in which the TAS is supported, and quality assurance. Work has started on updating radiation and energy deposition calculations using the current optics design and detailed information about geometry of relevant components. Work has begun on impedance calculations for the 1-to-2 beam pipe transition. Functional Specifications for both the TAN and TAS are being prepared.

<u>WBS 1.1.5 Inner Triplet System Design</u> With the addition of an Engineering Manager to the Project Office, we have re-evaluated definition of this task. System integration, e.g. configuration management, interface control, coordination of work at different laboratories, is the responsibility of the Engineering Manager for the Project as a whole, including the interaction region system. The task WBS 1.1.5 is now understood to be the engineering design of the inner triplet system, including the inner triplet itself, the feedboxes and the superconducting dipole D1. This addresses system design aspects which cover the inner triplet as a whole and are not specific to one of the sub-systems. Mike Lamm has replaced Tom Peterson as the level 3 manager for this task, but Tom will continue to be responsible for cryogenic and mechanical engineering of the inner

triplet system. A paper describing the cryogenic system design of the inner triplet, with authors from Fermilab, LBNL, and CERN, was presented at the 17th International Cryogenic Engineering Conference in July.

WBS 1.3.1 Superconductor Testing Upgrades to the test facility required to support the high production testing rate continue to make good progress. Installation of the second test magnet into its cryostat is nearing completion and assembly of the four sub-coils for the third magnet is under way. The design of the 25 kA power leads is complete and parts are being fabricated. Data acquisition, data analysis and database software upgrades are in process. The refrigeration system upgrades, previously scheduled to be completed by March 1999, will not be completed until several months after that due to expected conflicts for manpower with RHIC installation. As these upgrades are not required until the high rate testing gets underway in mid-FY2000, no problems are expected to result from this delay. With the resumption of tests following the extended shutdown for system upgrades the modest backlog of 4.2 K samples has been cleared out and one test run has been made at 1.9 K.

WBS 1.3.2 Superconducting Cable Production Support Evaluation of the prototype eddy current flaw detector indicate that additional measuring heads must be added to allow cold welds to be detected across the full width of the cable. The seven spare measuring heads for the cable measuring machines have been ordered. Tests are being performed with the LBNL cabling machine to understand sharp edge problems and cable quality with wire diameter variations across the tolerance band. Samples of cable for the BNL dipole program made from SSC outer wire from four vendors has been made for evaluation purposes.

WBS 1.4 Accelerator Physics Work at BNL and Fermilab to determine the field quality and alignment requirements for the US-provided magnet continues. Areas of concentration include studies of the dynamic aperture versus fractional tunes near the baseline operating point, studies to understand the relation between the dynamic aperture and the harmonic content of the IR quadrupoles via tracking and resonance analysis, evaluation of the amount of amplitude detuning due to the US-provided and other magnets, and the requirements on the relative field angle between the two apertures of the beam separation dipoles. Preparations have begun to include beam-beam effects in the tracking simulations. A BNL physicist spent several weeks at CERN assisting in the development of the insertion lattices for IR2 and IR8 and in the production of the Ring 2 lattice. Electron cloud studies have been expanded to include optical effects. Impedance calculations for the injection kickers have been completed. Design calculations related to instrumentation of the TAN and TAS are continuing. Jim Holt, the WBS level 3 manager for FNAL AP, has announced that he will leave Fermilab. Tanaji Sen will replace him as level 3 manager.

IV. Budget and Schedule Status

As noted above, we are not able to produce an accurate cost performance report due to technical difficulties and the simultaneous review and revision of the accelerated schedules against which we will track performance. We expect to be able to produce CPRs corresponding to the three months of this quarter within the coming weeks, which we will submit as an addendum to this report. A more detailed analysis of the budget and schedule status than is possible now will accompany the addendum.

The cumulative project inception-to-date funds status is summarized in 12 graphs and tables in Attachment 1. The figures are organized in four sets of three corresponding to the Project as a whole and to each laboratory's part of the project, with each set consisting of the total, operating, and equipment fund status. Each shows the expected obligation profile during the current fiscal year, the funds allocated (which slightly exceed the expected obligations), the actual expenditures, and the open commitments. The steps in the funds allocations in November and April are the allocations of the bulk of the FY1998 funds in two increments. The final allocation of FY1998 funds occurred in August. In September the funds previously earmarked for reimbursing CERN for agreed US industrial purchases was instead allocated to the laboratories as an advance on the FY1999 program, due to CERN's inability to invoice DOE before the end of the fiscal year. A corresponding amount of FY1999 funds have been deducted from the laboratory program and allocated for industrial purchases.

The operating funds expended are shown to exceed the allocated funds for several months. This is because initially we anticipated that the bulk of the funds would be operating money and expenses were accounted as such. When, several months into the fiscal year, we were informed that the Project would be funded mostly with equipment money, we corrected this error by fund transfers, which took place in March at BNL, May at Fermilab and September at LBNL; an overcorrection at Fermilab was undone in August. The negative incremental expense at BNL in May results from retroactive application of the new lower G&A rate. The large increment in open commitments at BNL in June represents the ordering of coil parts.

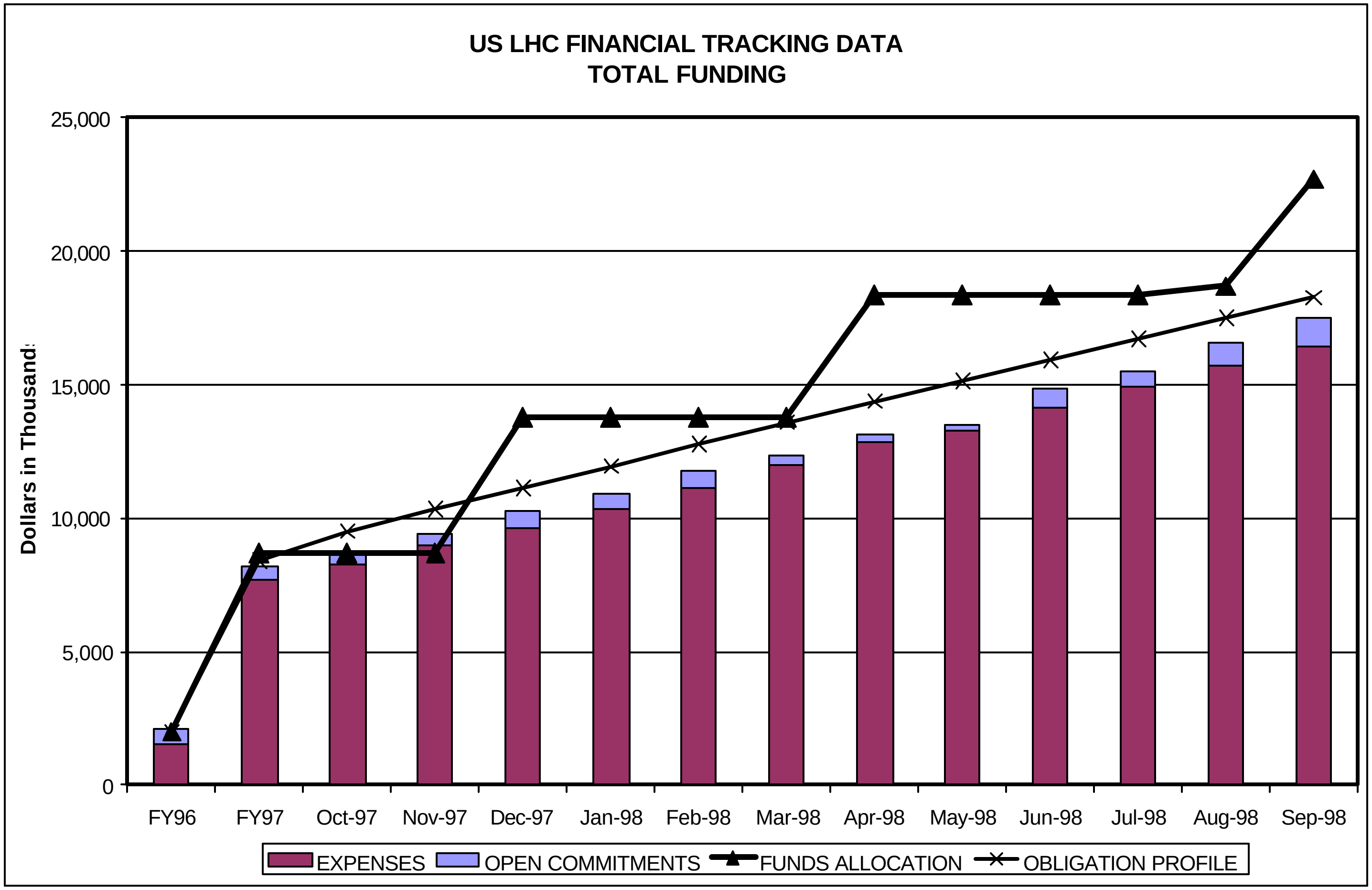
By the end of FY1998, the project had obligated \$17.5M, or 16% of the TPC. The actual obligations lag the planned profile by \$779K, the equivalent of about 1 month or 4% of the planned obligations. The lack of an accurate CPR makes it difficult to quantify how much of this difference is due to schedule versus cost deviations. Based on examination of those elements of the CPR which are believed to be accurate and making corrections for known errors, and on the basis of technical knowledge of the program progress, it is clear that most tasks are on or behind schedule by at most a few months, and that costs of all WBS level 3 tasks are close to the estimates so far.

Attachment 2 is the table of controlled milestones to level 3. Three milestones have been achieved this quarter: 3-1.1.2-1 IR Beam Separation Dipole Conceptual Design Review, 3-1.2.1-1 RF Region Beam separation Dipole Conceptual Design Review, and 3-1.3.2-2C Deliver powered Turkshead to CERN.

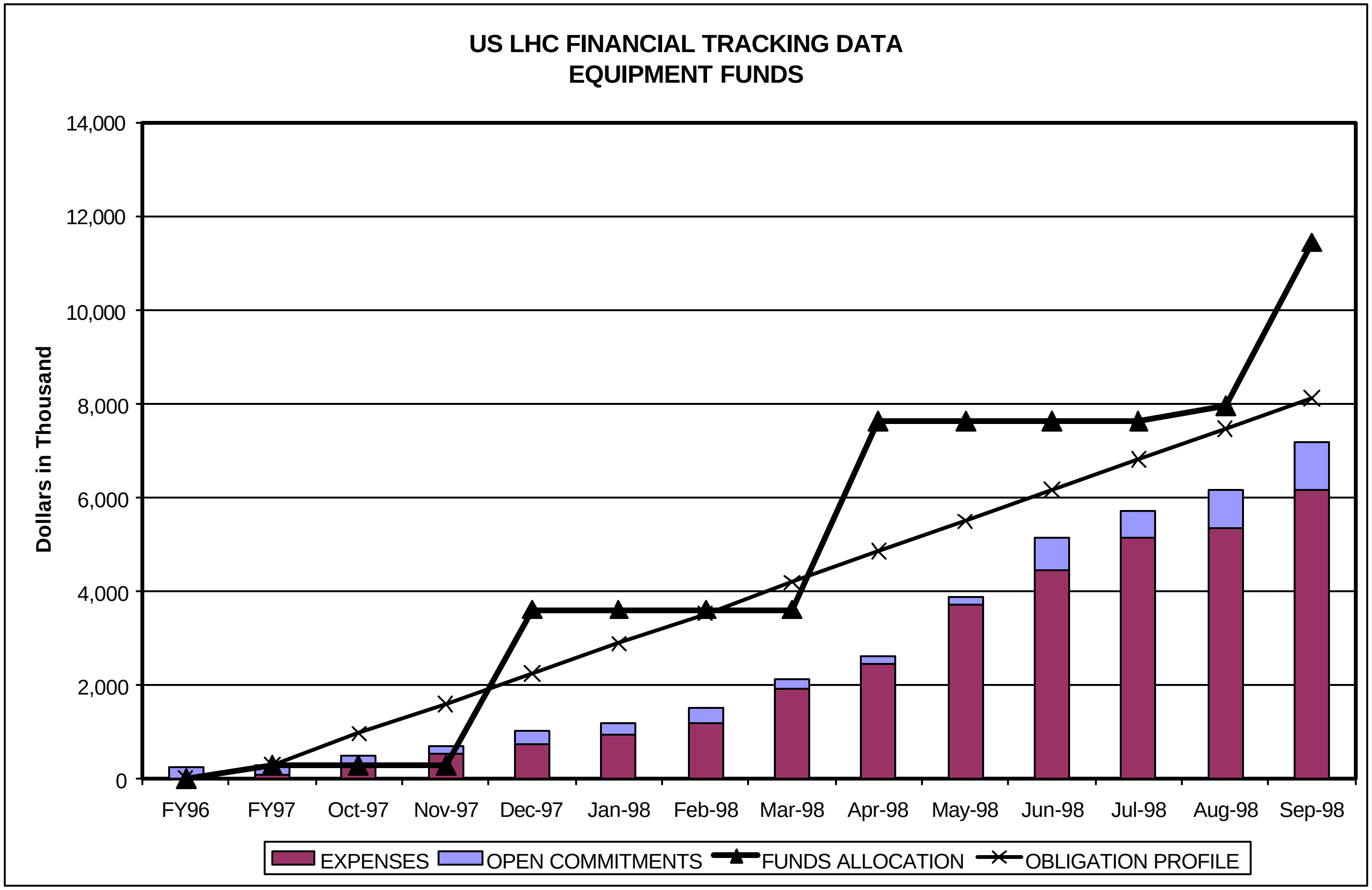
VI. Evaluation

With the Implementing Arrangement and Project Management Plan approved, the basic governing documents are in place and the project baseline is defined. Good technical progress is being made on all the subtasks. Overall, and in each of the subtasks, the project is on schedule, with deviations of at most a month or two, and the costs so far are close to those estimated. Communication with CERN continues to be good and the coordination with CERN is being put on a more formal basis. The main area of concern is the poor quench performance of the interaction region quadrupoles. Considerable effort is being directed at solving this problem, and the R&D program has been modified and expanded following a review of the program in July. The expanded R&D program will result in modest contingency usage, which will be the subject of a BCR to be submitted in the near future. If the results of the upcoming set of model magnet tests is favorable, no delay in the schedule of the full-scale prototype or the start of production as a result of the expanded R&D program.

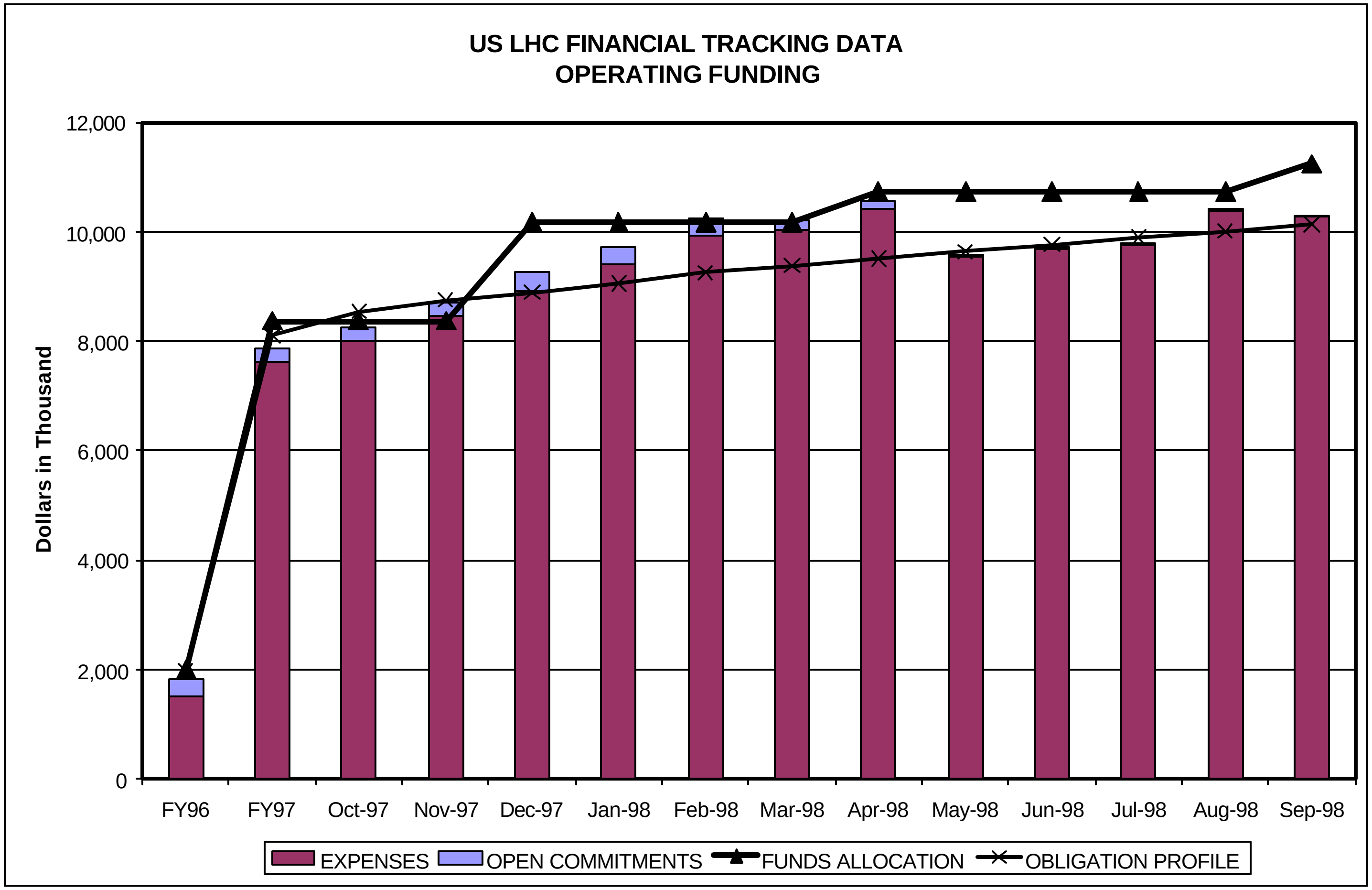
Attachment 1
Funds Tracking Data



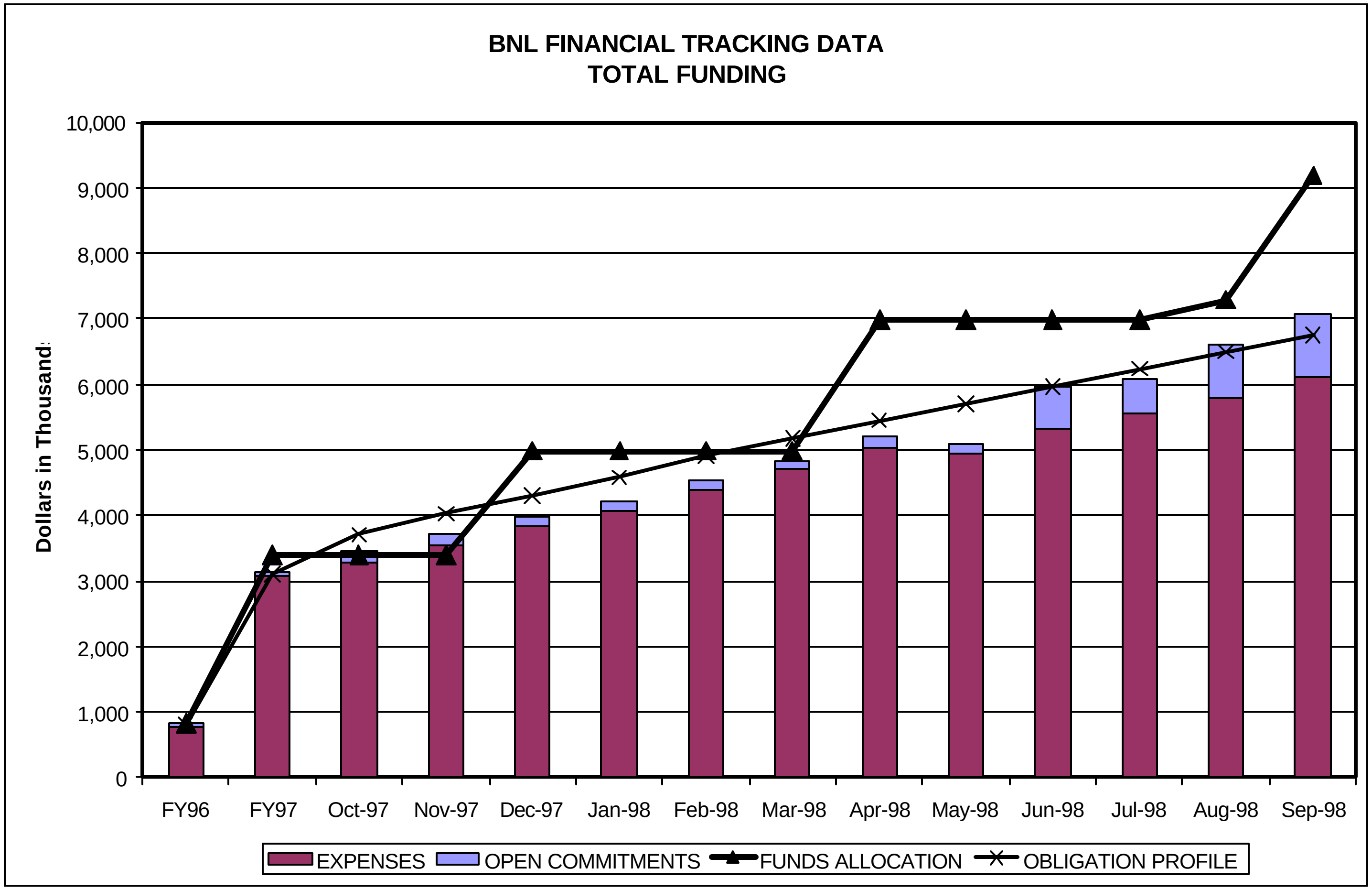
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	2,000	6,670	0	0	5,100	0	0	0	4,600	0	0	0	300	4,000
OBLIGATION PROFILE	1,962	6,427	1,116	839	789	803	839	790	793	761	789	787	781	776
EXPENSES	1,515	6,187	591	664	672	731	781	810	905	401	881	769	802	704
OPEN COMMITMENTS	296	253	326	284	391	209	261	189	229	187	694	586	850	1,182
CUMULATIVE														
FUNDS ALLOCATION	2,000	8,670	8,670	8,670	13,770	13,770	13,770	13,770	18,370	18,370	18,370	18,370	18,670	22,670
OBLIGATION PROFILE	1,962	8,390	9,505	10,344	11,134	11,936	12,776	13,566	14,359	15,120	15,909	16,696	17,476	18,252
EXPENSES	1,515	7,702	8,293	8,957	9,629	10,360	11,141	11,951	12,856	13,257	14,137	14,907	15,709	16,413
OPEN COMMITMENTS	561	450	474	426	630	544	599	377	289	187	689	597	851	1,060



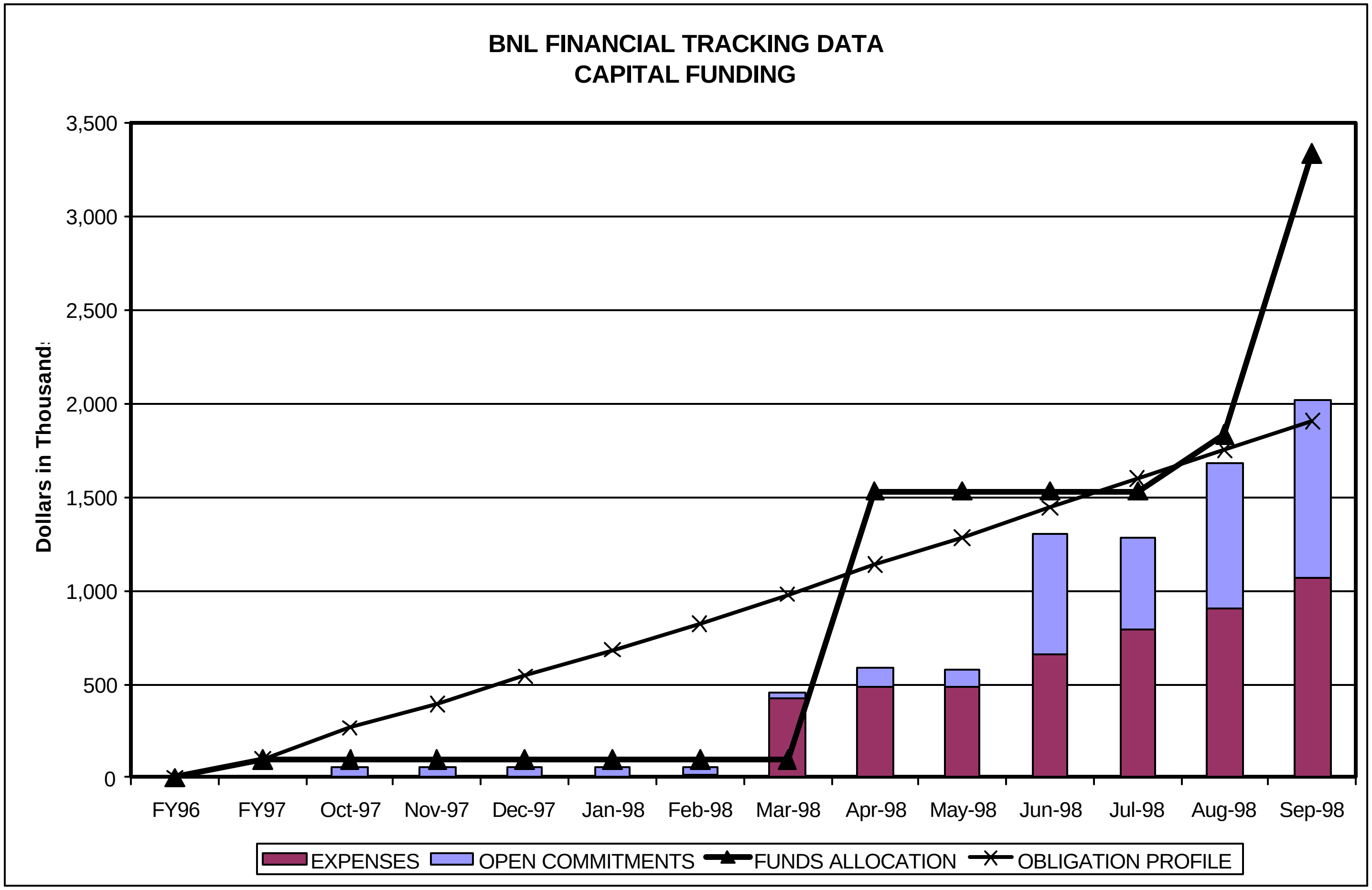
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	0	300	0	0	3,304	0	0	0	4,031	0	0	0	300	3,500
OBLIGATION PROFILE	0	300	666	630	648	642	641	658	663	641	662	660	655	652
EXPENSES	0	88	220	208	203	231	257	730	498	1,294	728	694	184	814
OPEN COMMITMENTS	0	0	105	35	59	54	79	143	112	142	679	560	827	1,162
CUMULATIVE														
FUNDS ALLOCATION	0	300	300	300	3,604	3,604	3,604	3,604	7,635	7,635	7,635	7,635	7,935	11,435
OBLIGATION PROFILE	0	300	966	1,597	2,245	2,887	3,528	4,186	4,849	5,490	6,152	6,811	7,466	8,118
EXPENSES	0	88	308	515	718	949	1,206	1,936	2,434	3,727	4,456	5,149	5,333	6,147
OPEN COMMITMENTS	265	197	202	178	298	253	291	203	172	142	674	571	828	1,040



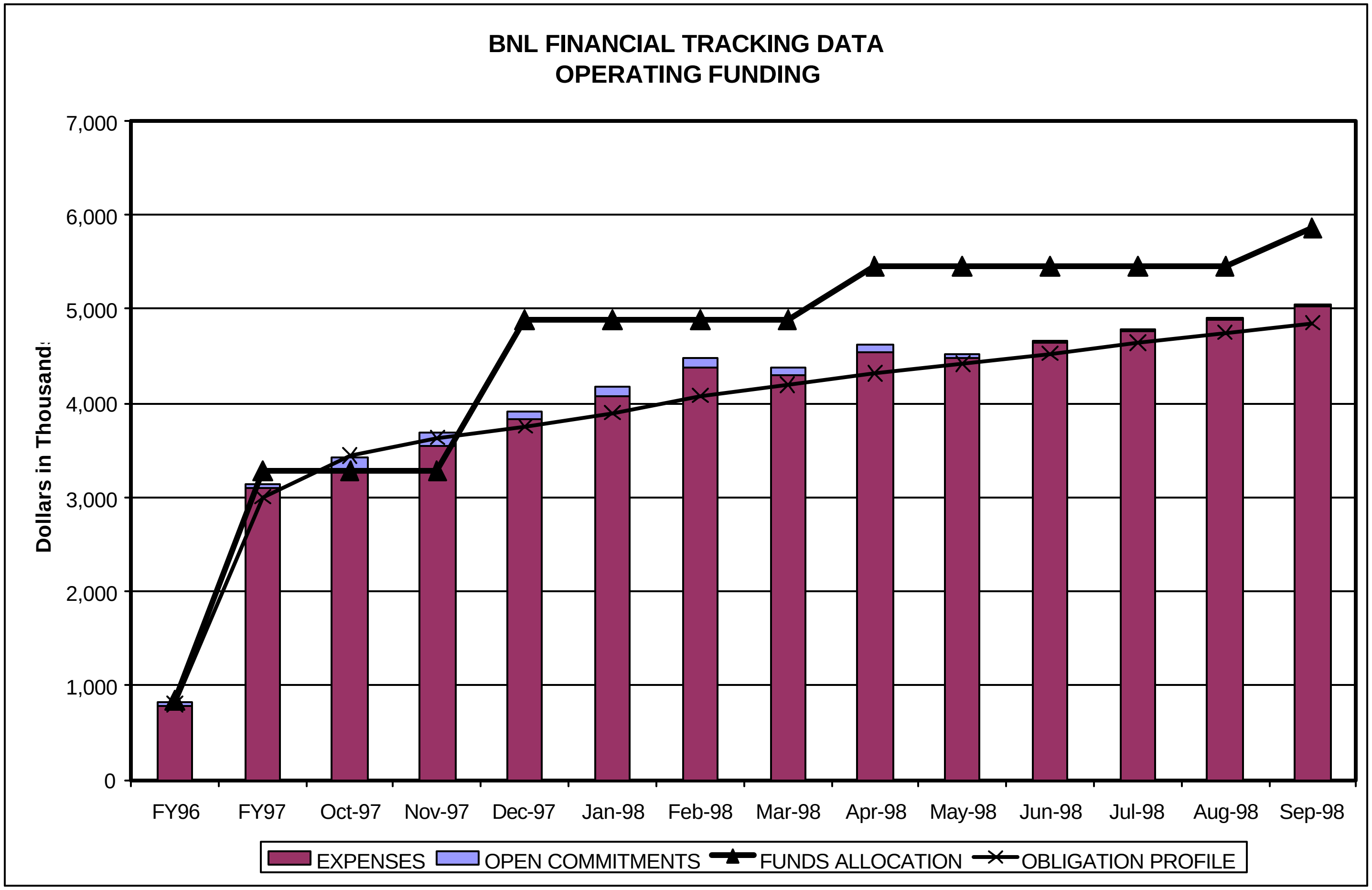
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	2,000	6,370	0	0	1,796	0	0	0	569	0	0	0	0	500
OBLIGATION PROFILE	1,962	6,127	449	209	141	161	198	132	130	121	127	127	126	124
EXPENSES	1,515	6,099	372	456	469	500	524	80	407	-893	152	76	618	-110
OPEN COMMITMENTS	296	253	221	248	332	156	182	46	117	45	16	26	23	20
CUMULATIVE														
FUNDS ALLOCATION	2,000	8,370	8,370	8,370	10,166	10,166	10,166	10,166	10,735	10,735	10,735	10,735	10,735	11,235
OBLIGATION PROFILE	1,962	8,090	8,539	8,748	8,889	9,049	9,248	9,380	9,510	9,630	9,757	9,884	10,010	10,134
EXPENSES	1,515	7,614	7,986	8,442	8,911	9,411	9,935	10,015	10,422	9,529	9,682	9,757	10,376	10,266
OPEN COMMITMENTS	296	253	271	248	332	291	308	175	117	45	16	26	23	20



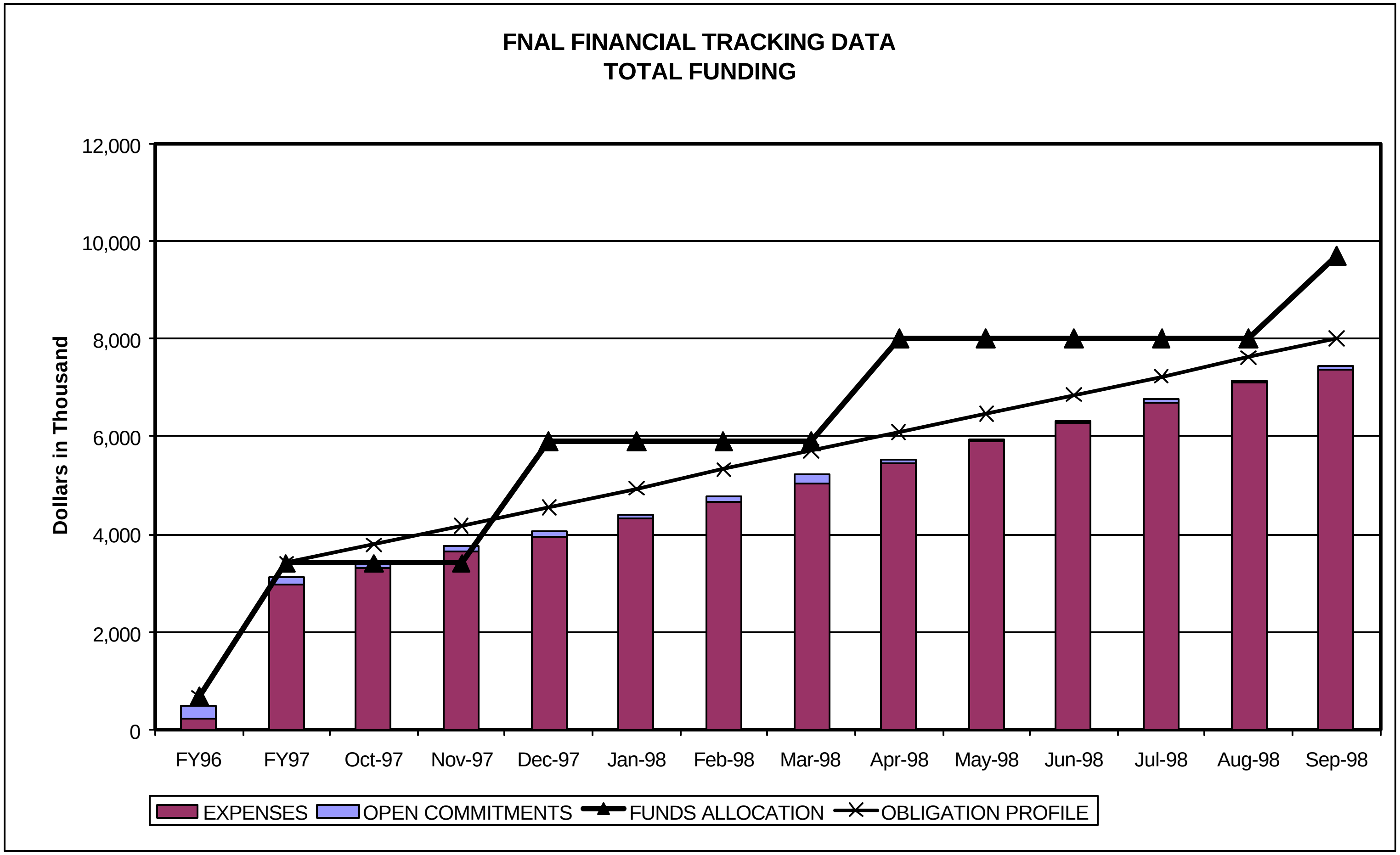
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	840	2,545	0	0	1,600	0	0	0	2,000	0	0	0	300	1,900
OBLIGATION PROFILE	802	2,302	598	321	272	285	322	273	275	244	271	269	263	258
EXPENSES	786	2,300	193	265	277	252	326	309	321	-76	357	238	241	305
OPEN COMMITMENTS	30	57	191	187	145	145	132	130	168	138	661	515	801	975
CUMULATIVE														
FUNDS ALLOCATION	840	3,385	3,385	3,385	4,985	4,985	4,985	4,985	6,985	6,985	6,985	6,985	7,285	9,185
OBLIGATION PROFILE	802	3,105	3,703	4,024	4,296	4,581	4,902	5,175	5,450	5,694	5,965	6,234	6,497	6,755
EXPENSES	786	3,086	3,279	3,544	3,822	4,074	4,400	4,708	5,029	4,954	5,311	5,549	5,790	6,095
OPEN COMMITMENTS	30	57	191	187	145	145	132	130	168	138	661	515	801	975



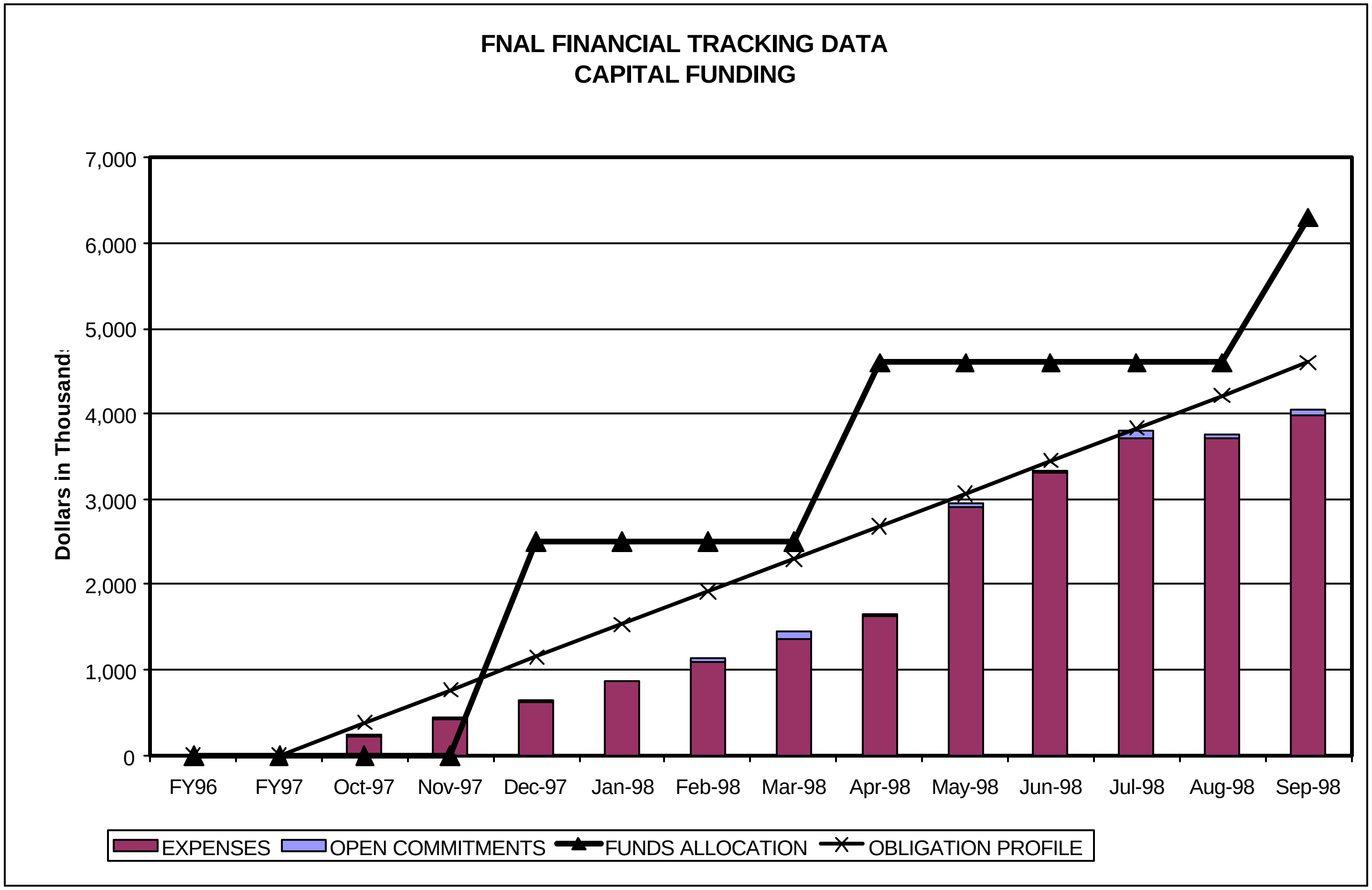
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	0	100	0	0	0	0	0	0	1,431	0	0	0	300	1,500
OBLIGATION PROFILE	0	100	165	129	147	140	140	157	162	140	160	158	154	150
EXPENSES	0	0	0	0	0	0	17	401	68	-5	179	129	117	159
OPEN COMMITMENTS	0	0	52	52	52	52	36	36	99	94	646	490	778	955
CUMULATIVE														
FUNDS ALLOCATION	0	100	100	100	100	100	100	100	1,531	1,531	1,531	1,531	1,831	3,331
OBLIGATION PROFILE	0	100	265	394	541	681	821	978	1,140	1,279	1,440	1,598	1,752	1,902
EXPENSES	0	0	0	0	0	0	17	418	486	481	660	789	906	1,065
OPEN COMMITMENTS	0	0	52	52	52	52	36	36	99	94	646	490	778	955



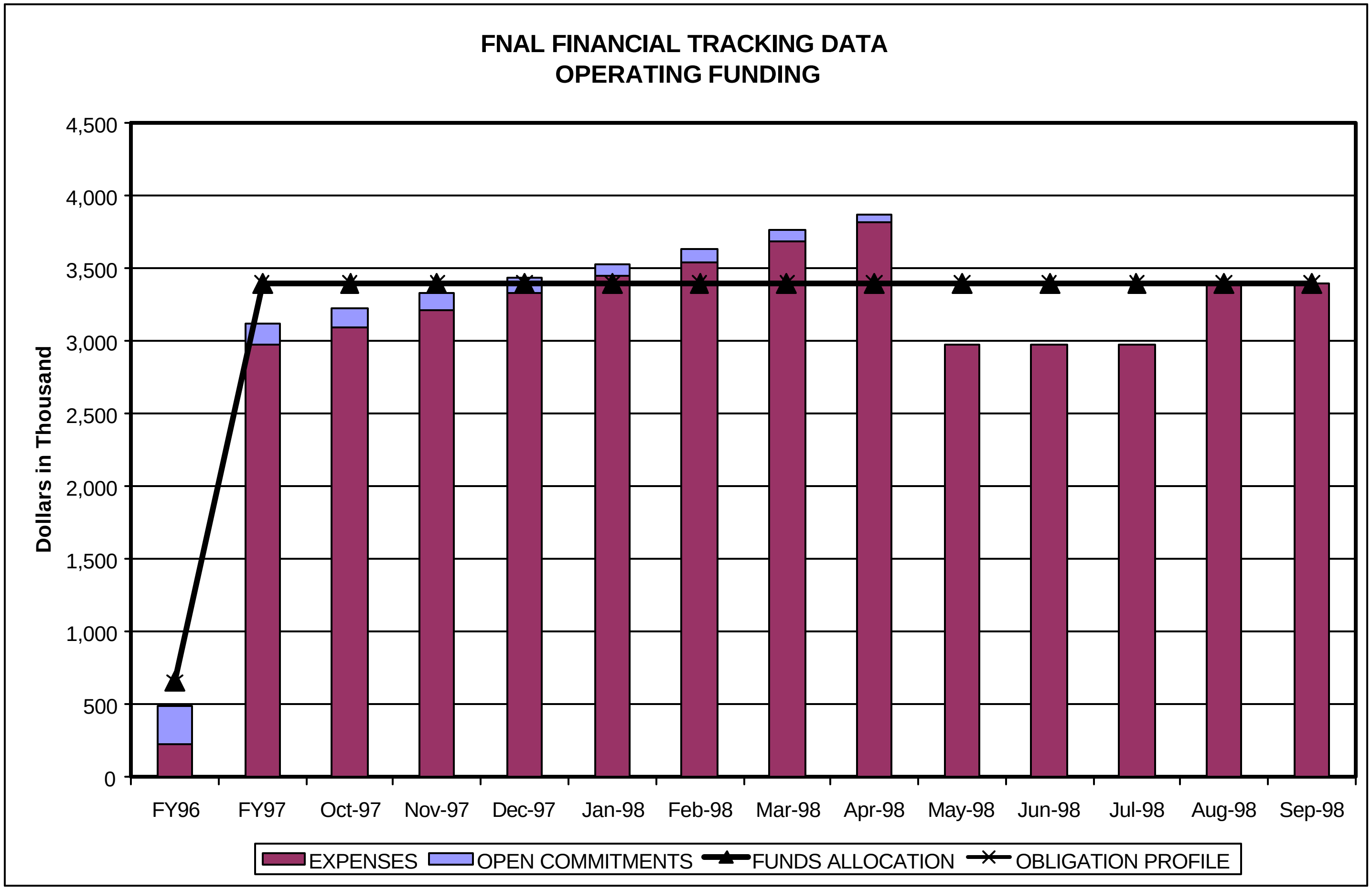
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	840	2,445	0	0	1,600	0	0	0	569	0	0	0	0	400
OBLIGATION PROFILE	802	2,202	433	193	125	144	182	116	114	104	111	111	109	108
EXPENSES	786	2,300	193	265	277	252	309	-92	253	-71	177	110	124	146
OPEN COMMITMENTS	30	57	139	135	93	93	96	93	69	45	16	26	23	20
CUMULATIVE														
FUNDS ALLOCATION	840	3,285	3,285	3,285	4,885	4,885	4,885	4,885	5,454	5,454	5,454	5,454	5,454	5,854
OBLIGATION PROFILE	802	3,005	3,437	3,630	3,755	3,899	4,081	4,197	4,310	4,414	4,525	4,636	4,745	4,853
EXPENSES	786	3,086	3,279	3,544	3,822	4,074	4,383	4,291	4,544	4,473	4,650	4,760	4,884	5,030
OPEN COMMITMENTS	30	57	139	135	93	93	96	93	69	45	16	26	23	20



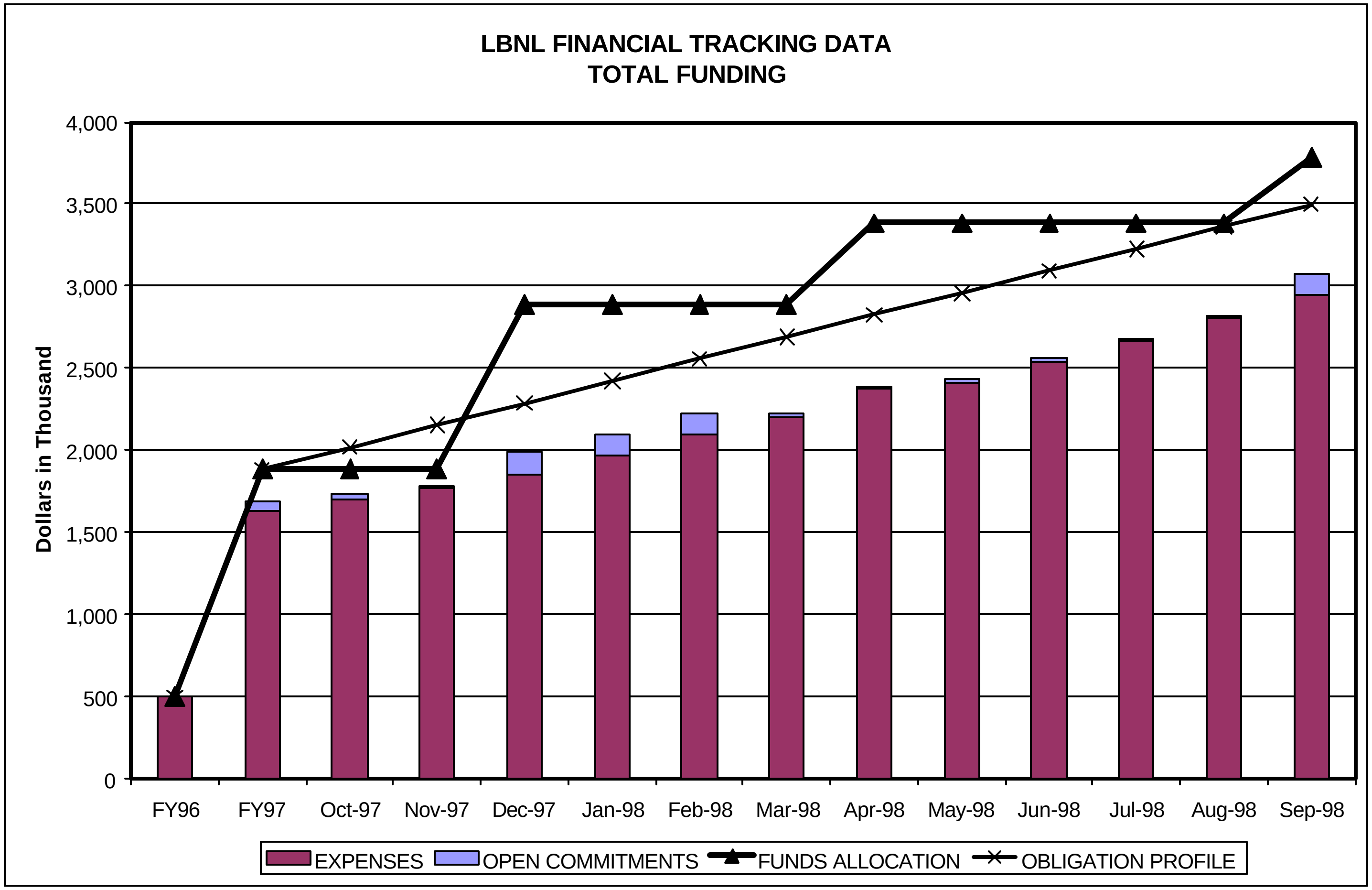
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	660	2,740	0	0	2,500	0	0	0	2,100	0	0	0	0	1,700
OBLIGATION PROFILE	660	2,740	383	383	383	383	383	383	383	383	383	383	383	383
EXPENSES	229	2,752	329	331	319	356	334	398	403	440	395	411	413	264
OPEN COMMITMENTS	265	147	150	126	110	75	126	166	73	49	28	82	50	85
CUMULATIVE														
FUNDS ALLOCATION	660	3,400	3,400	3,400	5,900	5,900	5,900	5,900	8,000	8,000	8,000	8,000	8,000	9,700
OBLIGATION PROFILE	660	3,400	3,783	4,167	4,550	4,933	5,317	5,700	6,083	6,467	6,850	7,233	7,617	8,000
EXPENSES	229	2,981	3,310	3,641	3,959	4,315	4,648	5,046	5,449	5,889	6,284	6,695	7,108	7,372
OPEN COMMITMENTS	265	147	150	126	110	75	126	166	73	49	28	82	50	85



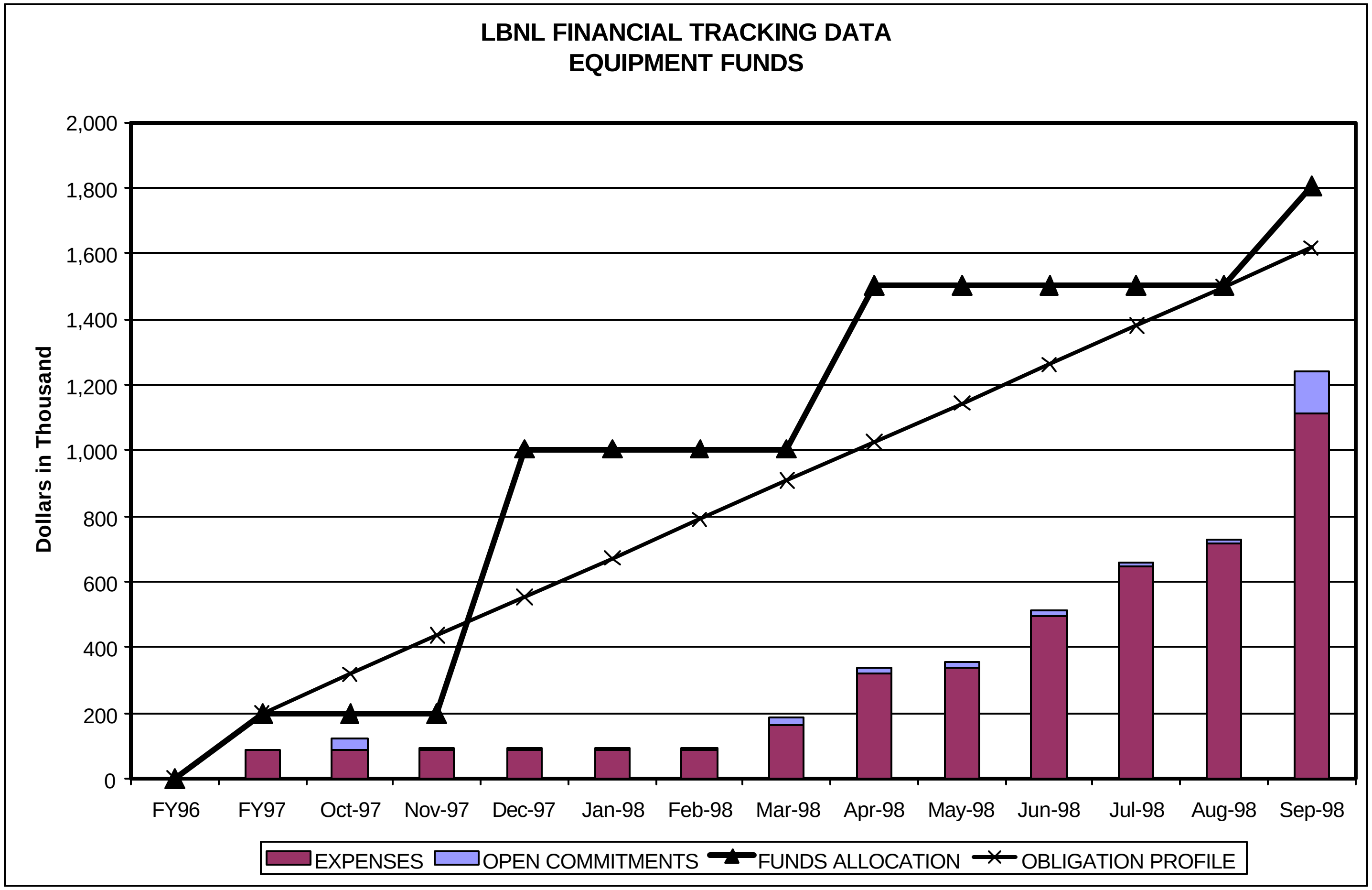
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION					2,500				2,100					1,700
OBLIGATION PROFILE			383	383	383	383	383	383	383	383	383	383	383	383
EXPENSES	0	0	219	208	203	231	240	256	270	1,283	395	411	-6	264
OPEN COMMITMENTS	0	0	18	13	7	2	42	85	24	49	28	82	50	85
CUMULATIVE														
FUNDS ALLOCATION	0	0	0	0	2,500	2,500	2,500	2,500	4,600	4,600	4,600	4,600	4,600	6,300
OBLIGATION PROFILE	0	0	383	767	1,150	1,533	1,917	2,300	2,683	3,067	3,450	3,833	4,217	4,600
EXPENSES	0	0	219	427	629	860	1,100	1,356	1,626	2,908	3,303	3,714	3,708	3,972
OPEN COMMITMENTS	0	0	18	13	7	2	42	85	24	49	28	82	50	85



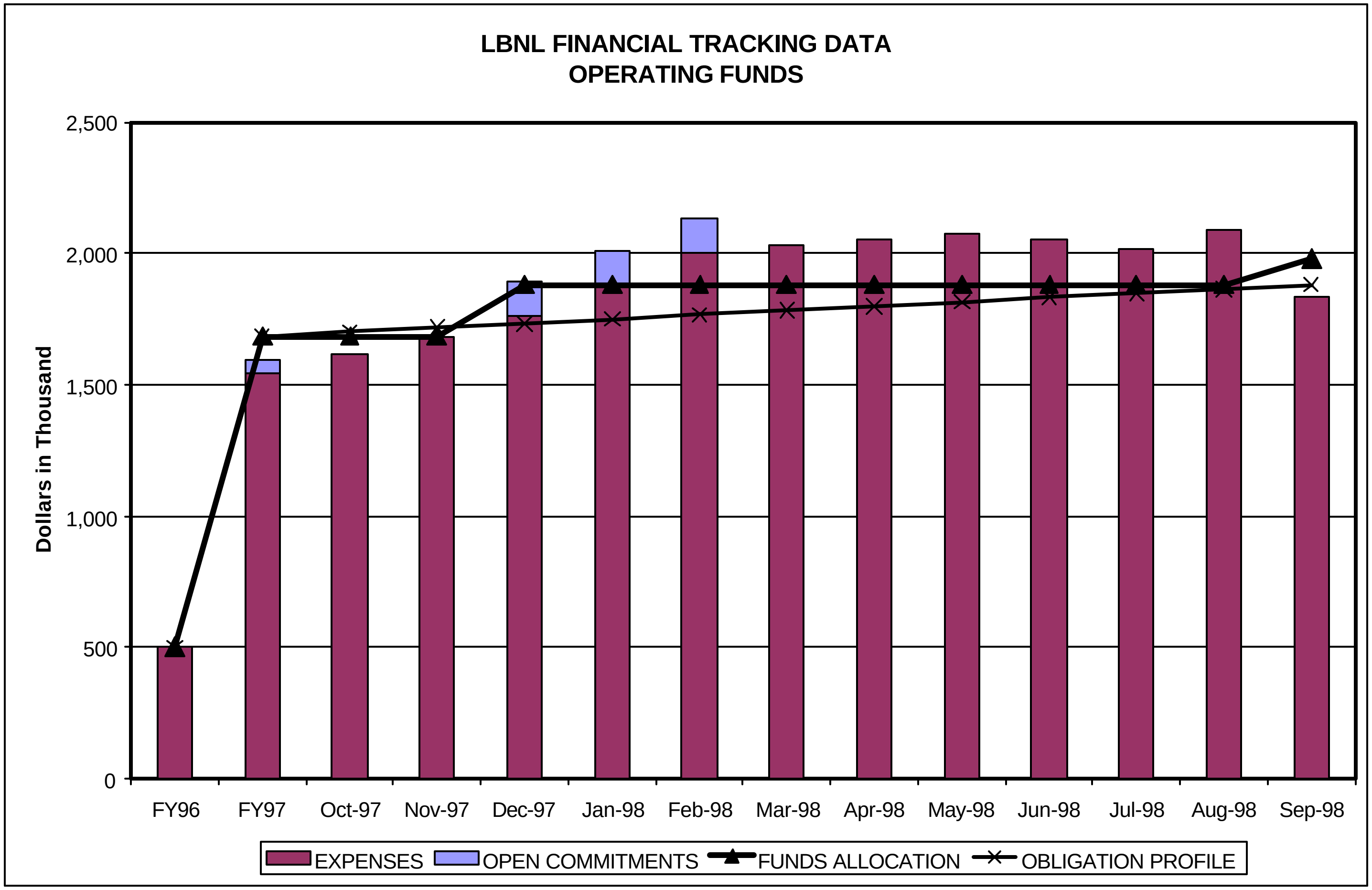
	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	660	2,740												
OBLIGATION PROFILE	660	2,740												
EXPENSES	229	2,752	110	123	116	125	93	142	133	-842	0	0	419	0
OPEN COMMITMENTS	265	147	132	113	103	73	84	82	49	0	0	0	0	0
CUMULATIVE														
FUNDS ALLOCATION	660	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400
OBLIGATION PROFILE	660	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400
EXPENSES	229	2,981	3,091	3,214	3,330	3,455	3,548	3,690	3,823	2,981	2,981	2,981	3,400	3,400
OPEN COMMITMENTS	265	147	132	113	103	73	84	82	49	0	0	0	0	0



	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	500	1,385	0	0	1,000	0	0	0	500	0	0	0	0	400
OBLIGATION PROFILE	500	1,385	134	134	134	134	134	134	134	134	134	134	134	134
EXPENSES	500	1,135	70	68	76	123	121	104	181	36	129	120	148	134
OPEN COMMITMENTS	0	50	-15	-30	136	-10	3	-107	-11	0	5	-11	-1	122
CUMULATIVE														
FUNDS ALLOCATION	500	1,885	1,885	1,885	2,885	2,885	2,885	2,885	3,385	3,385	3,385	3,385	3,385	3,785
OBLIGATION PROFILE	500	1,885	2,019	2,154	2,288	2,422	2,557	2,691	2,825	2,960	3,094	3,228	3,363	3,497
EXPENSES	500	1,635	1,705	1,772	1,848	1,971	2,093	2,196	2,378	2,414	2,543	2,663	2,811	2,945
OPEN COMMITMENTS	0	50	35	5	141	131	133	27	16	16	21	10	9	131



	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION		200			804				500					300
OBLIGATION PROFILE		200	118	118	118	118	118	118	118	118	118	118	118	118
EXPENSES	0	88	1	0	0	0	0	73	160	16	154	154	73	391
OPEN COMMITMENTS	0	0	35	-30	0	0	0	22	-11	0	5	-11	-1	122
CUMULATIVE														
FUNDS ALLOCATION	0	200	200	200	1,004	1,004	1,004	1,004	1,504	1,504	1,504	1,504	1,504	1,804
OBLIGATION PROFILE	0	200	318	436	554	672	790	908	1,026	1,144	1,262	1,380	1,498	1,616
EXPENSES	0	88	89	89	89	89	89	162	322	338	493	646	719	1,110
OPEN COMMITMENTS	0	0	35	5	5	5	5	27	16	16	21	10	9	131



	FY96	FY97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
INCREMENTAL														
FUNDS ALLOCATION	500	1,185			196									100
OBLIGATION PROFILE	500	1,185	16	16	16	16	16	16	16	16	16	16	16	16
EXPENSES	500	1,047	69	68	76	123	121	31	21	20	-25	-34	75	-257
OPEN COMMITMENTS	0	50	-50	0	136	-10	3	-128	0	0	0	0	0	0
CUMULATIVE														
FUNDS ALLOCATION	500	1,685	1,685	1,685	1,881	1,881	1,881	1,881	1,881	1,881	1,881	1,881	1,881	1,981
OBLIGATION PROFILE	500	1,685	1,701	1,718	1,734	1,750	1,767	1,783	1,799	1,816	1,832	1,848	1,865	1,881
EXPENSES	500	1,547	1,616	1,684	1,759	1,882	2,004	2,034	2,055	2,075	2,050	2,017	2,092	1,835
OPEN COMMITMENTS	0	50	0	0	136	126	128	0	0	0	0	0	0	0

Attachment 2
Milestone Status

US LHC Accelerator Project Level 1 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
1 - 1		Project Start	1 Oct 1995		1 Oct 1995
1 - 2 C		Decision as to whether or not the U.S. Project includes RF region quadrupoles	1 Jul 2001		
1 - 3		Project Completion	30 Sep 2005		

US LHC Accelerator Project Level 2 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.1 Interaction Regions				
2 -1.1- 1		Begin 1st inner triplet quadrupole model magnet	1 Jul 1997		1 Jul 1997
2 -1.1- 2		Complete inner triplet quadrupole model magnet program phase 1	1 Jun 1999		
2 -1.1- 3		Complete inner triplet quadrupole model magnet program phase 2	1 Jan 2000		
2 -1.1- 4		Complete tests of prototype HTS power leads	1 Jan 2000		
2 -1.1- 5		Begin absorber fabrication	1 Nov 2000		
2 -1.1- 6		Complete inner triplet quadrupole prototype magnet program	1 Dec 2000		
2 -1.1- 7		Begin interaction region beam separation dipole production assembly	1 Mar 2001		
2 -1.1- 8		Begin inner triplet feedbox fabrication	1 Mar 2001		
2 -1.1- 9		Begin inner triplet quadrupole production assembly	15 Apr 2001		
2 -1.1- 10		Complete 1st inner triplet quadrupole magnet	1 Nov 2001		
2 -1.1- 11 C		Delivery of D2 for IR8 left	1 Apr 2002		
2 -1.1- 12		Complete inner triplet feedbox fabrication	1 May 2002		
2 -1.1- 13 C		Delivery of all inner triplet system components for IR8 left (MQX, DFBX, D1)	1 Oct 2002		
2 -1.1- 14 C		Delivery of D2 for IR5 left	1 Nov 2002		
2 -1.1- 15		Complete absorber fabrication	1 Dec 2002		
2 -1.1- 16 C		Delivery of all inner triplet system components for IR8 right (MQX, DFBX, D1)	1 Jan 2003		
2 -1.1- 17 C		Delivery of D2 for IR8 right	1 Feb 2003		
2 -1.1- 18		Complete interaction region beam separation dipole production assembly	1 Mar 2003		
2 -1.1- 19 C		Delivery of all inner triplet system components for IR1 left (MQX,DFBX,TAS,TAN)	1 Jul 2003		
2 -1.1- 20 C		Delivery of D2 for IR2 right	1 Sep 2003		
2 -1.1- 21		Begin ionization chamber fabrication	1 Nov 2003		
2 -1.1- 22 C		Delivery of D2 for IR1 left	1 Dec 2003		
2 -1.1- 23 C		Delivery of all inner triplet system components for IR5 left (MQX,DFBX,TAS,TAN)	1 Jan 2004		
2 -1.1- 24 C		Delivery of D2 for IR5 right	1 Mar 2004		
2 -1.1- 25 C		Delivery of all inner triplet system components for IR5 right(MQX,DFBX,TAS,TAN)	1 Apr 2004		
2 -1.1- 26 C		Delivery of all inner triplet system components for IR2 right (MQX, DFBX, D1)	1 Apr 2004		
2 -1.1- 27 C		Delivery of all inner triplet system components for IR1 right(MQX,DFBX,TAS,TAN)	1 Jul 2004		

US LHC Accelerator Project Level 2 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
2 -1.1- 28 C	Delivery of D2 for IR1 right	1 Aug 2004		
2 -1.1- 29 C	Delivery of D2 for IR2 left	1 Sep 2004		
2 -1.1- 30	Complete inner triplet quadrupole production	1 Sep 2004		
2 -1.1- 31	Complete ionization chamber fabrication	15 Sep 2004		
2 -1.1- 32 C	Delivery of all inner triplet system components for IR2 left (MQX, DFBX, D1)	1 Oct 2004		
2 -1.1- 33	Interaction Region task complete	30 Sep 2005		
	WBS 1.2 RF Region			
2 -1.2- 1	Begin assembly of 1st dipole model magnet	1 Sep 1999		
2 -1.2- 2	Complete dipole model magnet program	1 Aug 2000		
2 -1.2- 3	Begin RF region beam separation dipole production assembly	1 Sep 2000		
2 -1.2- 4 C	Delivery of D3, D4 for IR4 right	1 Jan 2002		
2 -1.2- 5	Complete RF region beam separation dipole production assembly	1 Oct 2002		
2 -1.2- 6 C	Delivery of D3, D4 for IR4 left	1 Nov 2002		
2 -1.2- 7	RF Region task complete	30 Sep 2005		
	WBS 1.3 Superconducting Wire and Cable			
2 -1.3- 1	All cable production support equipment delivered to CERN	1 Mar 1999		
2 -1.3- 2	Complete SC testing facility upgrades	1 Jun 1999		
2 -1.3- 3	Series wire and cable testing complete	1 Oct 2004		
2 -1.3- 4	Superconducting Wire and Cable task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
	WBS 1.1.1 Interaction Region Quadrupoles			
3 -1.1.1- 1	Inner triplet quadrupole (MQX) cold mass conceptual design review	15 Oct 1996		15 Oct 1996
3 -1.1.1- 2	Begin 1st quadrupole model magnet	1 Jul 1997		1 Jul 1997
3 -1.1.1- 3	Quench heaters for model magnet program phase 1 delivered, LBNL to FNAL	1 Jun 1998		1 Jun 1998
3 -1.1.1- 4	Cable and wedges for model magnet program phase 1 delivered, LBNL to FNAL	1 Jun 1998		1 Jun 1998
3 -1.1.1- 5	MQX cryostat conceptual design review	15 Dec 1998		
3 -1.1.1- 6 C	MQX cold mass to cryostat interface specification approved	1 Mar 1999		
3 -1.1.1- 7	Complete model magnet program phase 1	1 Mar 1999		
3 -1.1.1- 8	Cable and wedges for model magnet program phase 2 delivered, LBNL to FNAL	1 Mar 1999		
3 -1.1.1- 9 C	MQXB field quality specifications approved	1 Jul 1999		
3 -1.1.1- 10 C	MQX functional specifications approved	1 Jul 1999		
3 -1.1.1- 11 C	MQX to correction coil interface specification approved	1 Jul 1999		
3 -1.1.1- 12 C	Inner triplet compensation and correction scheme approved	1 Jul 1999		
3 -1.1.1- 13	Start production of cable and wedges for prototype and production MQXB	1 Aug 1999		
3 -1.1.1- 14	Complete model magnet program phase 2	1 Oct 1999		
3 -1.1.1- 15 C	MQX alignment specifications approved	1 Nov 1999		
3 -1.1.1- 16 C	All MQX interface specifications approved	1 Nov 1999		
3 -1.1.1- 17	MQX Engineering Design Review	1 Dec 1999		
3 -1.1.1- 18 C	Delivery to FNAL of BPMs	1 Aug 2000		
3 -1.1.1- 19	Complete prototype magnet program	1 Oct 2000		
3 -1.1.1- 20	MQX Production Readiness Review	1 Oct 2000		
3 -1.1.1- 21	Begin assembly of first MQXB	1 Oct 2000		
3 -1.1.1- 22	Complete production of cable and wedges for production MQXB	1 Jan 2001		
3 -1.1.1- 23 C	Delivery to FNAL of 1st MQXA	1 May 2001		
3 -1.1.1- 24 C	Delivery to FNAL of 1st correction coil	1 Jul 2001		
3 -1.1.1- 25	Begin assembly of first MQXA	1 Aug 2001		
3 -1.1.1- 26	IR8 left MQX ready to deliver	1 Sep 2002		
3 -1.1.1- 27	IR8 right MQX ready to deliver	1 Dec 2002		
3 -1.1.1- 28	IR1 left MQX ready to deliver	1 Jun 2003		
3 -1.1.1- 29	IR1 right MQX ready to deliver	1 Oct 2003		
3 -1.1.1- 30	IR5 left and right MQX ready to deliver	1 Oct 2003		
3 -1.1.1- 31	IR2 left and right MQX ready to deliver	1 Feb 2004		
3 -1.1.1- 32	All spare MQX ready to deliver	1 Jul 2004		
3 -1.1.1- 33	Interaction Region Quadrupoles task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
	WBS 1.1.2 Interaction Region Dipoles			
3 -1.1.2- 1	Beam Separation Dipole Conceptual Design Review (see Note 2)	1 Aug 1998		16 Jul 1998
3 -1.1.2- 2 C	D1,D2 field quality specifications approved	1 Feb 1999		
3 -1.1.2- 3 C	All D1,D2 functional and interface specifications approved	1 Jul 1999		
3 -1.1.2- 4	Superconducting wire for IR dipoles delivered by LBNL to BNL	1 Feb 2000		
3 -1.1.2- 5	Beam Separation Dipole Engineering Design Review (see Note 2)	1 Mar 2000		
3 -1.1.2- 6	Beam Separation Dipole Production Readiness Review (see Note 2)	1 Jun 2000		
3 -1.1.2- 7 C	Delivery by CERN to BNL of all CERN-provided D2 cryostat parts	1 Jul 2000		
3 -1.1.2- 8	Begin assembly of 1st D2	1 Dec 2000		
3 -1.1.2- 9	D2 production complete	1 Jan 2002		
3 -1.1.2- 10	Begin assembly of 1st D1	1 Feb 2002		
3 -1.1.2- 11	D1 production complete	1 Dec 2002		
3 -1.1.2- 12	Interaction Region Dipole task complete	30 Sep 2005		
	WBS 1.1.3 Interaction Region Cryogenic Feed Boxes			
3 -1.1.3- 1	Cryogenic Feed Box (DFBX) Conceptual Design Review	15 Dec 1998		
3 -1.1.3- 2 C	DFBX functional specification approved	1 Mar 1999		
3 -1.1.3- 3	DFBX interface specification review	1 May 1999		
3 -1.1.3- 4 C	DFBX interface specification approved	1 Jul 1999		
3 -1.1.3- 5	Complete tests of prototype HTS leads	1 Oct 1999		
3 -1.1.3- 6	DFBX Engineering Design Review	1 Jul 2000		
3 -1.1.3- 7	DFBX Production Readiness Review	1 Nov 2000		
3 -1.1.3- 8	Begin fabrication of 1st DFBX	1 Dec 2000		
3 -1.1.3- 9	IR1 and IR5 DFBXs ready to ship	1 Sep 2001		
3 -1.1.3- 10	IR2 and IR8 DFBXs ready to ship	1 Feb 2002		
3 -1.1.3- 11	Interaction Region Cryogenic Feed Box task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.1.4 Interaction Region Absorbers				
3 -1.1.4- 1 C		TAN and TAS functional specifications approved	1 Jan 1999		
3 -1.1.4- 2 C		TAN and TAS interface specifications approved	1 Mar 1999		
3 -1.1.4- 3		TAN and TAS Absorber Conceptual Design Review	1 Mar 1999		
3 -1.1.4- 4		Instrumentation Conceptual Design Review	1 Mar 1999		
3 -1.1.4- 5 C		ISR jacks delivered to LBNL	1 May 1999		
3 -1.1.4- 6 C		z-placement of TAN approved	1 Jul 1999		
3 -1.1.4- 7 C		TAS support design approved	1 Jul 1999		
3 -1.1.4- 8		Interaction Region Absorber Engineering Design Review	1 Jul 2000		
3 -1.1.4- 9		Interaction Region Absorber Production Readiness Review	1 Jul 2000		
3 -1.1.4- 10		Begin fabrication of TAN and TAS components	1 Aug 2000		
3 -1.1.4- 11		Begin assembly of TAN and TAS	1 Sep 2001		
3 -1.1.4- 12		Instrumentation Engineering Design Review	1 Apr 2002		
3 -1.1.4- 13 C		Ionization chamber functional and interface specifications approved	1 Jul 2002		
3 -1.1.4- 14		Complete assembly of TAN and TAS	1 Sep 2002		
3 -1.1.4- 15		Instrumentation Production Readiness Review	1 Jul 2003		
3 -1.1.4- 16		Begin procurement and fabrication of instrumentation	1 Aug 2003		
3 -1.1.4- 17		Complete fabrication of instrumentation	1 Jul 2004		
3 -1.1.4- 18 C		Ionization chambers shipped to CERN	1 Oct 2004		
3 -1.1.4- 19		Interaction Region Absorber task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
	WBS 1.2.1 RF Region Dipoles			
3 -1.2.1- 1	Beam Separation Dipole Conceptual Design Review	1 Aug 1998		16 Jul 1998
3 -1.2.1- 2 C	D3,D4 field quality specifications approved	1 Feb 1999		
3 -1.2.1- 3 C	D3,D4 functional and interface specifications approved	1 Jul 1999		
3 -1.2.1- 4	Superconducting wire for IR dipoles delivered by LBNL to BNL	1 Feb 1999		
3 -1.2.1- 5	Begin assembly of 1st dipole model magnet	15 Jul 1999		
3 -1.2.1- 6	Complete cold test of 1st dipole model magnet	1 Dec 1999		
3 -1.2.1- 7	Beam Separation Dipole Engineering Design Review	1 Mar 2000		
3 -1.2.1- 8	Complete model magnet program	1 May 2000		
3 -1.2.1- 9	Beam Separation Dipole Production Readiness Review	1 Jun 2000		
3 -1.2.1- 10	Begin assembly of 1st D4	1 Jun 2000		
3 -1.2.1- 11 C	Delivery by CERN to BNL of all CERN-provided cryostat parts	1 Jul 2000		
3 -1.2.1- 12	D4 production complete	1 May 2001		
3 -1.2.1- 13	Begin assembly of 1st D3	1 Aug 2001		
3 -1.2.1- 14	First 2 D3s complete	1 Dec 2001		
3 -1.2.1- 15	D3 production complete	1 Jul 2002		
3 -1.2.1- 16	RF Region Dipole task complete	1 Nov 2003		
	WBS 1.3.1 Superconductor testing			
3 -1.3.1- 1 C	Complete superconductor testing facility upgrades	1 Jul 1999		
3 -1.3.1- 2 C	Begin pre-series testing	1 Mar 1999		
3 -1.3.1- 3 C	Begin series testing	1 Mar 2000		
3 -1.3.1- 4 C	Series testing complete	1 Oct 2004		
	WBS 1.3.2 SC Cable Production Support			
3 -1.3.2- 1 C	Deliver 4 Cable Measuring Machines (CMM) to CERN	1 Oct 1997		1 Oct 1997
3 -1.3.2- 2 C	Deliver powered Turkshead to CERN	1 Jul 1998		1 Jul 1998
3 -1.3.2- 3 C	Deliver eddy current flaw detector to CERN	1 Jul 1999		
3 -1.3.2- 4 C	Deliver spare CMM measuring heads to CERN	1 Jan 1999		